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The Paleozoic evolution of Central Tianshan: Geochemical and geochronological evidence

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ABSTRACT

A suite of Paleozoic granitoids in Central Tianshan was studied for both geochemistry and geochronology in an effort to constrain their origin and tectonic setting. We combined LA-ICP-MS dating of zircon, standard geochemical analyses and Hf-isotopic studies of zircon to develop our tectonic model. Based on our analysis, the granitoids formed in three distinctive stages: ~450–400 Ma, ~370–350 Ma and ca. 340 Ma. The first stage (450–400 Ma) granitoids exhibit metaluminous, magnesian, high-K to shoshonitic characteristics of I-type granitoids (arc-setting), that are enriched in LREE relative to HREE with high $(La/Yb)_{CN}$ values, show negative Eu anomaly and are depleted in Nb, Ta and Ti. This phase of granitoid emplacement was most likely related to the southward subduction of the Paleo-Tianshan Ocean beneath the Tarim block and the subsequent Central Tianshan arc. In contrast, the second stage granitoids (370–350 Ma) are distinctly different and are classified as calc-alkaline or shoshonitic plutons with a weak positive Eu anomaly. Within the second stage granitoids, it appears that the earlier (~365 Ma) granitoids fit within the A-type field whereas the younger (~352 Ma) granitoids plot within the post-collisional potassic field. These granitoids formed during collisions between Central Tianshan and the Tuha terrane that occurred along the northern margin of Central Tianshan. Lastly, the ca. 340 Ma granitoids are typical of volcanic arc granitoids again that probably formed during the northward subduction of the South Tianshan Ocean beneath the Central Tianshan landmass or the subsequent southward subduction of the residual Paleo-Tianshan Ocean.

The Hf isotopic data of zircons from all the studied granitoids were pooled and yielded three prominent Hf T_{DM}^{C} model age populations: ca. 2400 Ma, ca. 1400 Ma and ca. 1100 Ma. The Hf-data shows a significant input of juvenile crust in addition to crustal recycling. We interpret these three phases of juvenile crustal addition to phases of global growth of continental crust (~2400 Ma), the addition of juvenile crust during the breakup of the Columbia supercontinent (~1400 Ma) and the assembly of Rodinia (~1100 Ma).

1. Introduction

The Central Asian Orogenic Belt (CAOB) or the Central Asian Orogenic System (CAOS), also known as "Altaids" in the literature (Sengör et al., 1993) is sandwiched between the European and Siberian Cratons in the north and the Tarim and North China Cratons in the south (Fig. 1a; Xiao et al., 2003; Li, 2006; Charvet et al., 2007; Xiao et al., 2008; Charvet et al., 2011; Han et al., 2011). The arcuate CAOB is one of the largest Phanerozoic orogens on Earth and collectively encompasses immense areas of China, Mongolia, Uzbekistan, Kazakhstan, Russia and their surroundings (Seltmann et al., 2003; Xiao et al., 2003; Levashova et al., 2011). It is also famous for the significant Phanerozoic continental growth and tectonic assembly of continental and oceanic terranes that resulted from the complicated accretion/collision processes of various magmatic arcs, accretionary complexes, microcontinents and seamounts. All these phenomena are thought to be related to the closure of the Paleo-Asian Ocean during the Paleozoic (Coleman, 1989; Zonenshain et al., 1990; Jahn et al., 2000; Shu et al., 2002; Jahn et al., 2004; Xiao et al., 2004; Yakubchuk, 2004; Kröner et al., 2007; Wang et al., 2007a; Windley et al., 2007; Kelty et al., 2008; Xiao et al., 2009; Charvet et al., 2011; Wang et al., 2011a). The CAOB thus provides a perfect laboratory for us to probe the genesis of orogenic belt, the accretion–collision process and the growth of continental crust. While the geography of the CAOB is well established, some crucial questions concerning the architecture's tectonic history remain ambiguous.

The Tianshan orogenic belt (SW CAOB, Fig. 1b), also spelled "Tian Shan" or "Tien Shan" in the literature plays a crucial role in the development of the CAOB (Shu et al., 2004; Kröner et al., 2007; Wang et al., 2007a,b; Windley et al., 2007; Shu et al., 2011a). The Tianshan orogenic belt extends E–W for more than 3000 km from eastern Xinjiang (NW China) to central Uzbekistan and contains the record of multi-phase tectonothermal evolution (Gao et al., 1998; Brookfield, 2000; Shu et al.,

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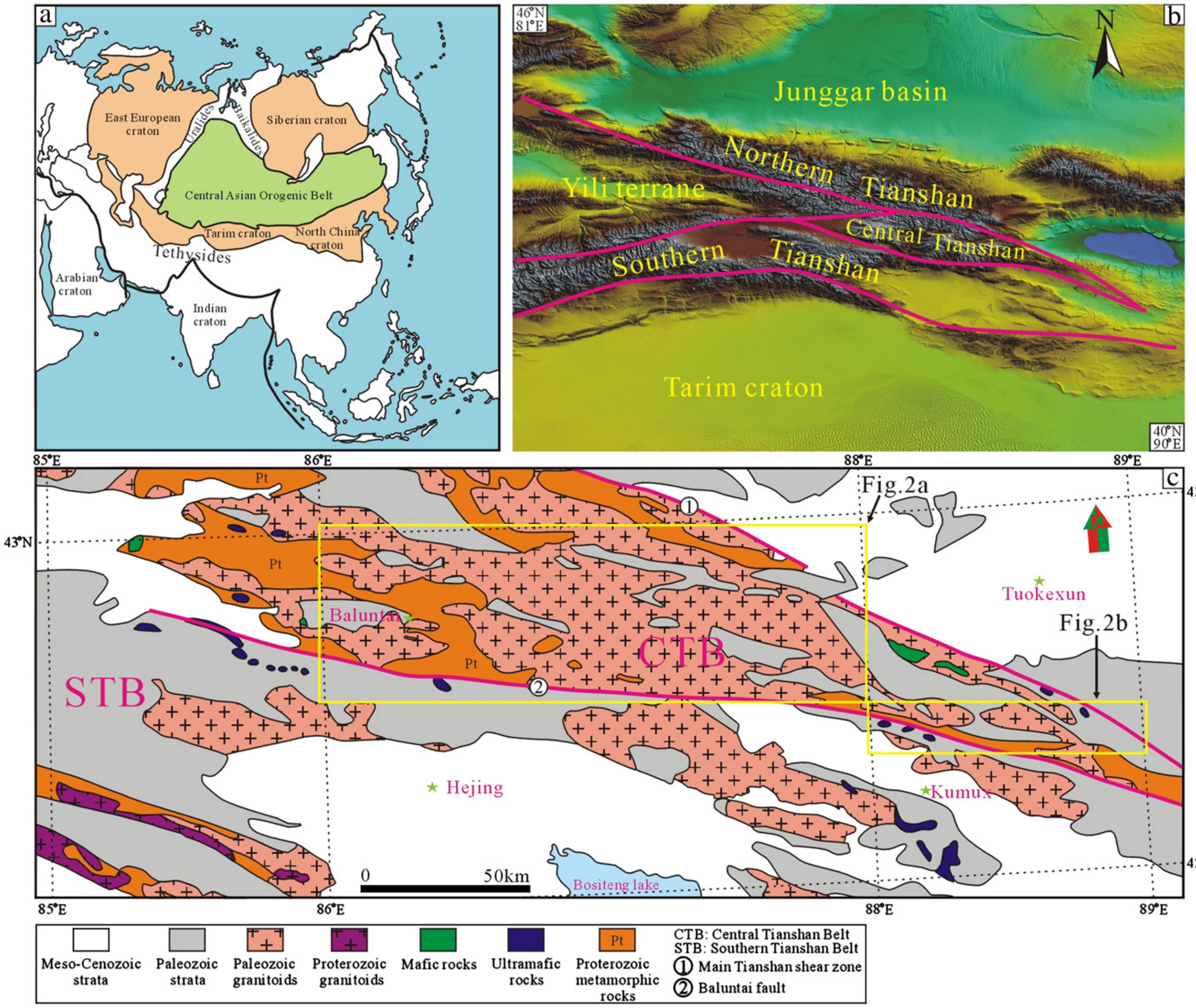

Fig. 1. (a) Tectonic framework of the Central Asian Orogenic Belt (after Xiao et al., 2010). (b) Tectonic framework of Central Tianshan and Tarim. (c) Simplified geological map of Central Tianshan (modified from XBGMR, 1992).

2004; Klemd et al., 2005; Charvet et al., 2007; Xiao et al., 2008; Gao et al., 2009; Xiao et al., 2009; B. Wang et al., 2010). As a late Paleozoic collisional and accretionary orogen, the Tianshan belt was formed by two main stages of N–S directed accretion/collision during Paleozoic (Windley et al., 1990; Allen et al., 1992; Shu et al., 1999; Charvet et al., 2001; Charvet et al., 2004; Wang et al., 2011a), and was strongly modified by subsequent large-scale strike-slip faulting (Laurent–Charvet et al., 2002, 2003).

Tectonically, the Chinese Tianshan (within the Xinjiang area) is subdivided into the South, Central and North Tianshan belts (Shu et al., 1999, 2002; Charvet et al., 2007, 2011). The western segment of the Chinese Tianshan meets the Yili Block (Fig. 1c), that is commonly correlated with the Central Tianshan microcontinent and called the Yili-Central Tianshan terrane (Allen et al., 1992; Gao et al., 1998; Gao and Klemd, 2003). It is also possible that the Yili Block may be regarded as the western equivalent of the North Tianshan volcanic arc. This has been argued on the basis of lithological differences between the Central Tianshan and the Yili Block (see Charvet et al., 2004; Wang et al., 2007b).

The Central Tianshan microcontinent (or Central Tianshan) constitutes a critical component of the Tianshan belt, which in turn is an important part of the CAOB (Charvet et al., 2007; Wang et al., 2008; Lin et al., 2009; B. Wang et al., 2010; Charvet et al., 2011). Therefore a clear understanding of tectonic events within the Central Tianshan will have a direct impact on the evolutionary history of the CAOB.

The paleogeographic evolution of the Paleo-Asian Ocean is controversial due, in no small part, to the fragmentary nature of the blocks within the CAOB. One model posits that during the early Paleozoic, the Paleo-Asian Ocean resembled the current-day situation in the SW Pacific that consists of an archipelago of microcontinents and magmatic arcs (Shu et al., 2001; Windley et al., 2007; Xiao et al., 2008; Han et al., 2010). According to many models, the microcontinents within the CAOB originated from Baltica, Siberia or the Tarim craton (Sengör et al., 1993; Sengör and Natal'in, 1996).

The early Paleozoic development of the CAOB (in general) and the Tarim block and Central Tianshan (in particular) are contentious. This is due to the lack of high-quality paleomagnetic data for the blocks in question (see Collins et al., 2003; Levashova et al., 2011). One model (Wilhem et al., 2012) positions the Tarim block at the northeastern Cimmerian margin of Gondwana with the Central Tianshan components nearby, but scattered across the Paleo-Asian Ocean (de Jong et al., 2006). In contrast, other authors have argued extensively that the Central Tianshan block was part of Tarim during the Precambrian